Electrical Measurements

Code: EPM1202

Lecture: 4 Tutorial: 2 Total: 6

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Electrodynamic instruments used as Wattmeters

The wattmeter is often used to measure power in three-phase systems

For a balanced circuit, only one wattmeter is used

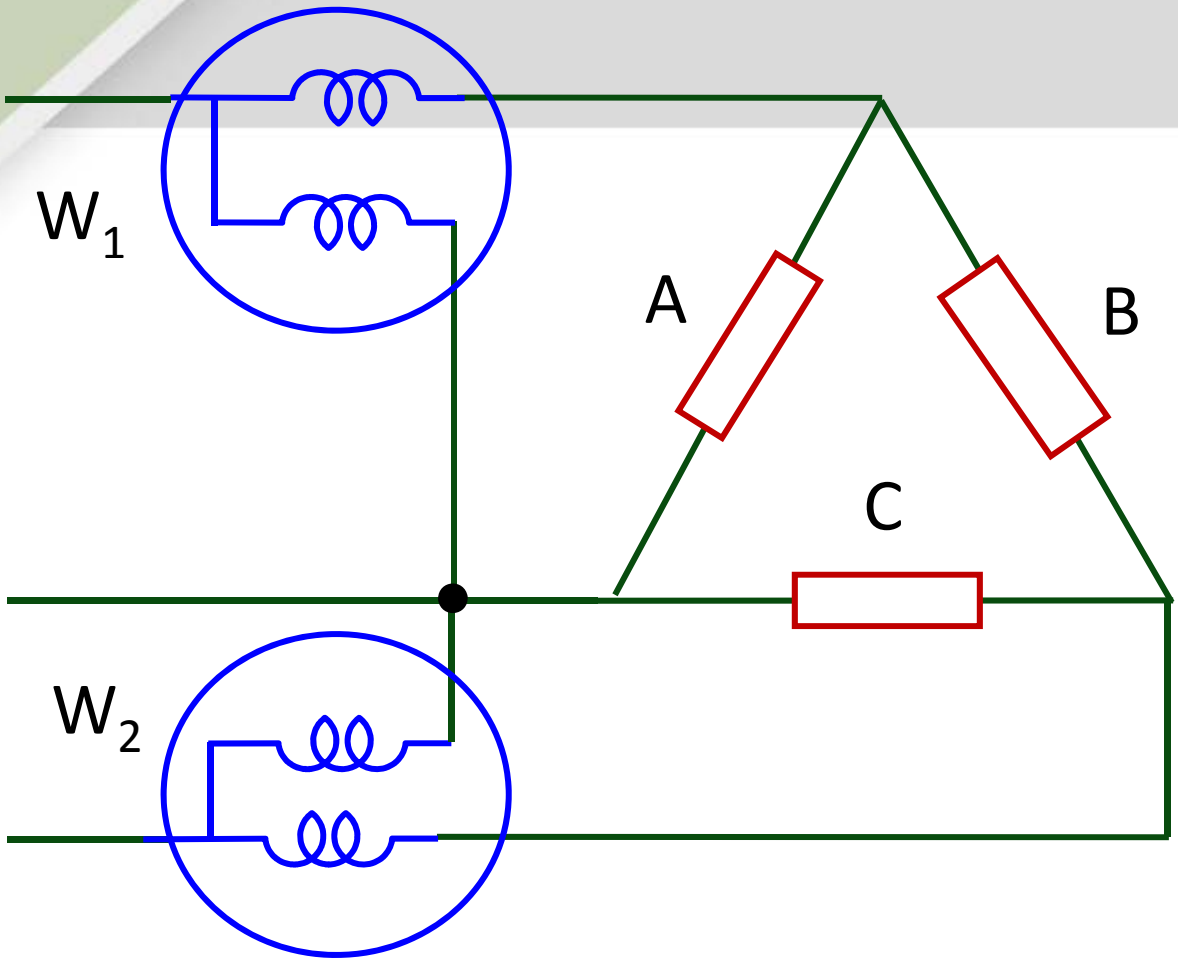
Three wattmeters can be used between the live and the neutral for each phase

Only two wattmeters can be used to measure power in a three-phase system

The sum of powers indicated by two wattmeters is equal to the total power in the system

This dependence is universal and holds for symmetrical or non-symmetrical circuits

Electrodynamic instruments used as Wattmeters



The total power of the circuit is: $P_{total} = P_{W1} + P_{W2}$

Thermocouple instrument

Used to sense and measure temperatures

A thermocouple instrument is a combination of a PMMC instrument and one or more thermopiles

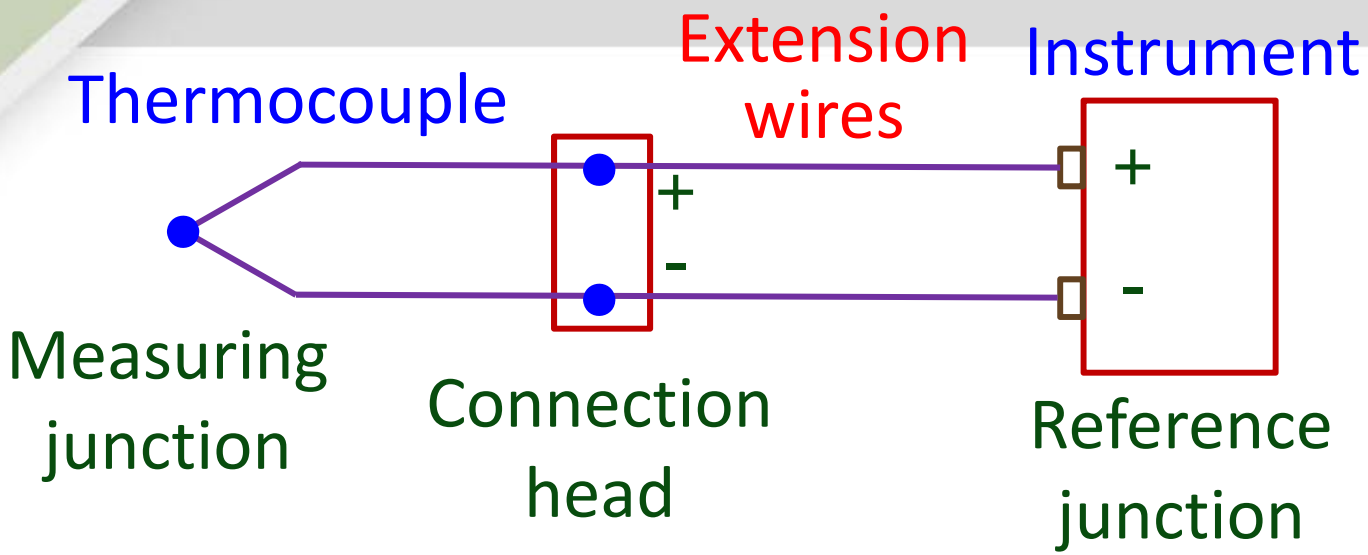
The ***thermopile*** consists of one or more thermocouples and a heater

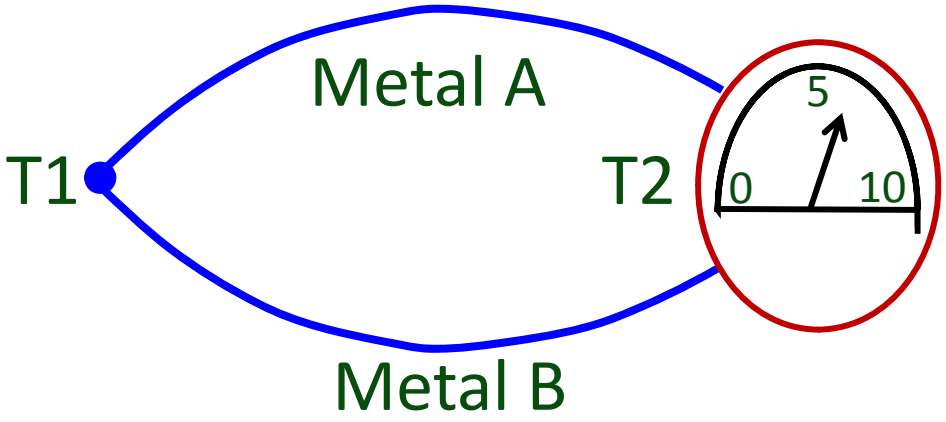
The current to be measured passes through the heater to produce heat

The released heat generates thermal electromotive force (e.m.f.) between the ends of the thermocouple

The e.m.f. is measured by the permanent-magnet instrument

Thermocouple instrument





Thermocouple instrument

Thermocouple instruments provide relatively high accuracy over a wide-range of frequencies

The accuracy is independent of current waveform

They are used for both ac and dc

Readings of thermocouple instruments depend on the ambient temperature

They consume relatively high power

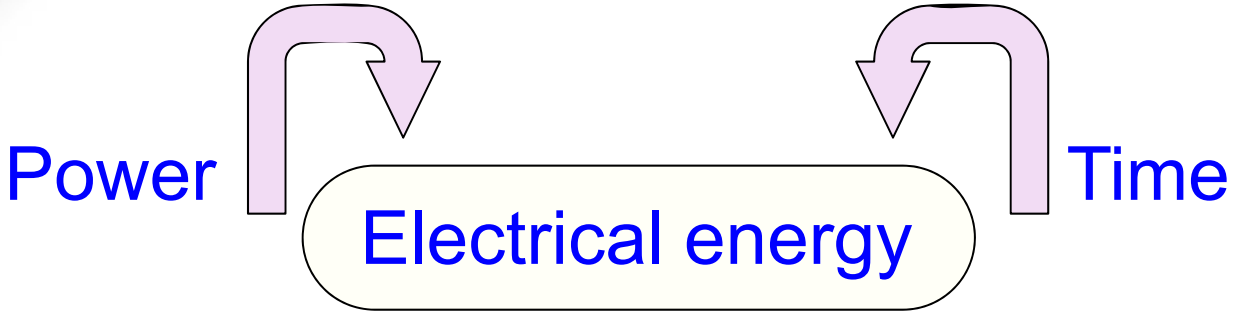
They are used for measuring the effective value of the strength of alternating current

Current range is from microamperes to several tens of amperes

Frequency range is from several tens of hertz to several hundred megahertz (error of 1–5 percent)

Energy meters

Energy is the time integral of electrical power



An idea is to use a continuous rotation of a disc, rather than a deflection

Speed → proportional to power

Number of revolutions → proportional to time

Energy meters

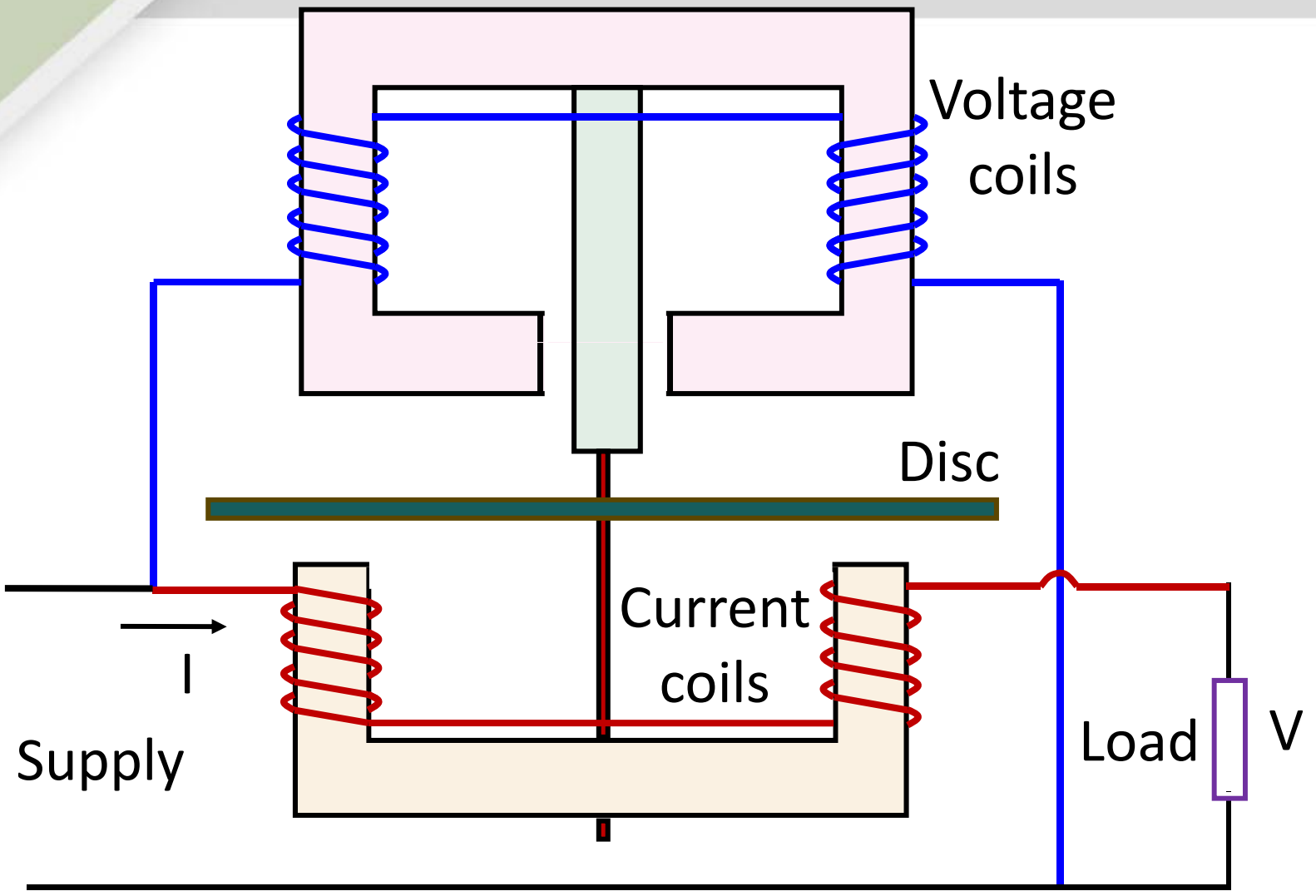
The a.c. energy meter “kWh meter” is usually of the induction type

The basis is the instantaneous values of current and voltage

The effect of power factor angle would automatically be taken into account

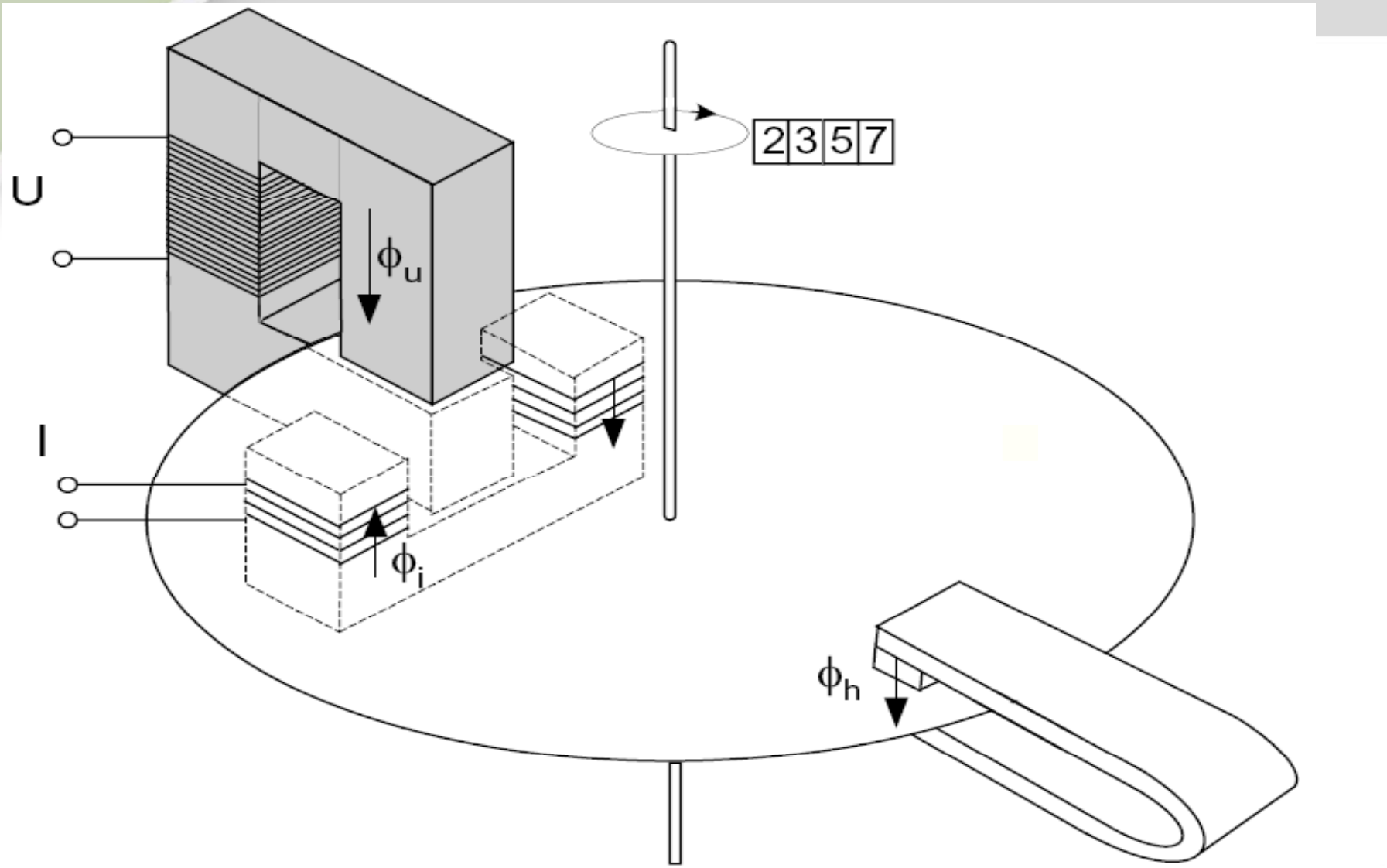
Energy meters

Configuration of the induction type watt-hour meter



Energy meters

Configuration of the induction type watt-hour meter

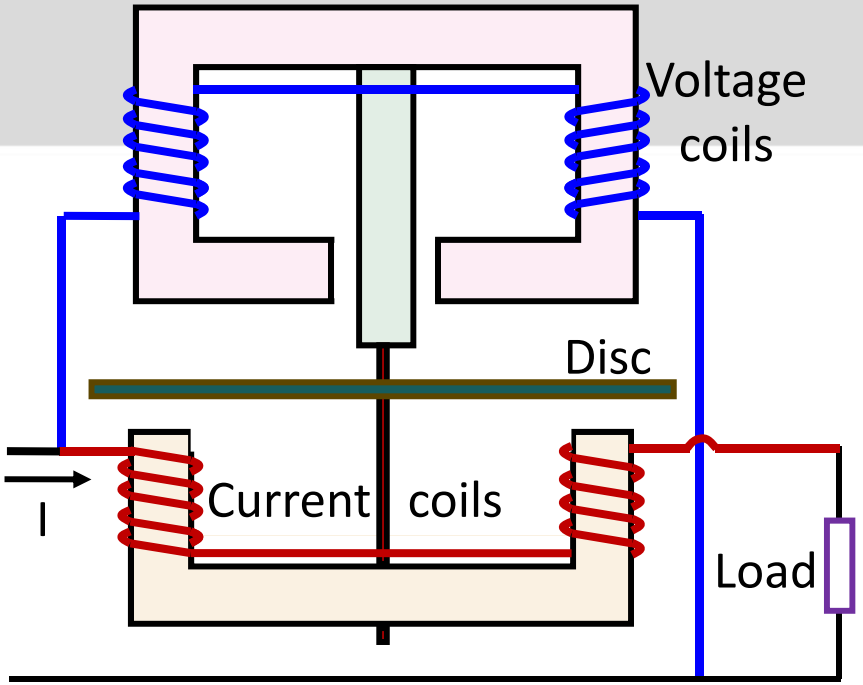


Energy meters

There are two cores supplied by two currents producing two fluxes

The currents depends on the current and voltage

The flow of the fluxes in a rotating aluminium disc produces eddy currents



The interaction between the eddy currents and the fluxes produces a rotating torque "T_r"

The torque depends on the currents and the phase angles between them

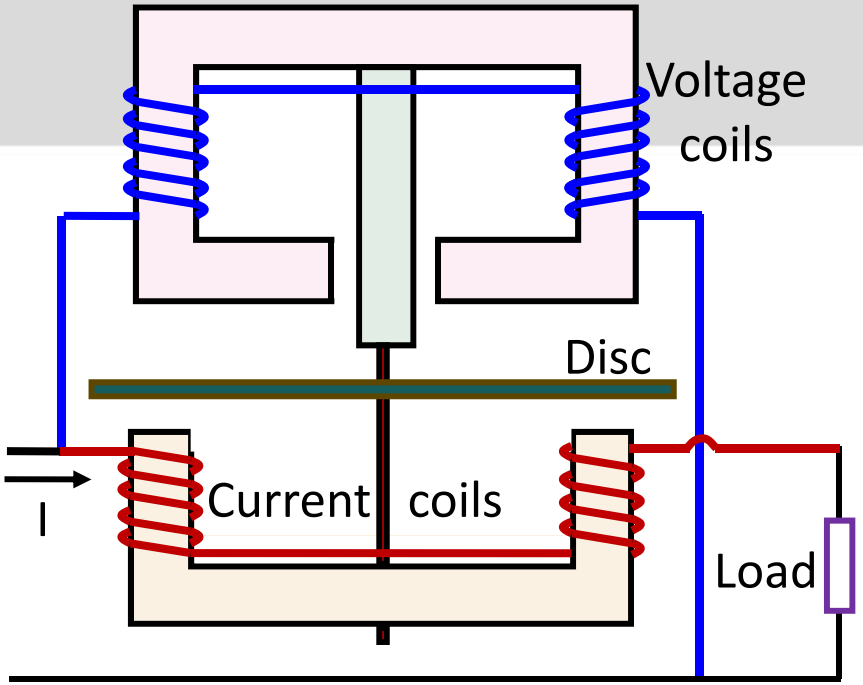
$$T_r = k \cdot I_1 \cdot I_2 \cdot \sin \phi_{12}$$

Energy meters

The first current is proportional to the measured current

The second current is proportional to the voltage

Due to large inductivity of the voltage core the current "I_2" is shifted in phase by almost "90◦" with respect to the voltage



sin (ϕ_{12}) is almost the cos (ϕ), where ϕ is the angle between the current and the voltage.

Energy meters

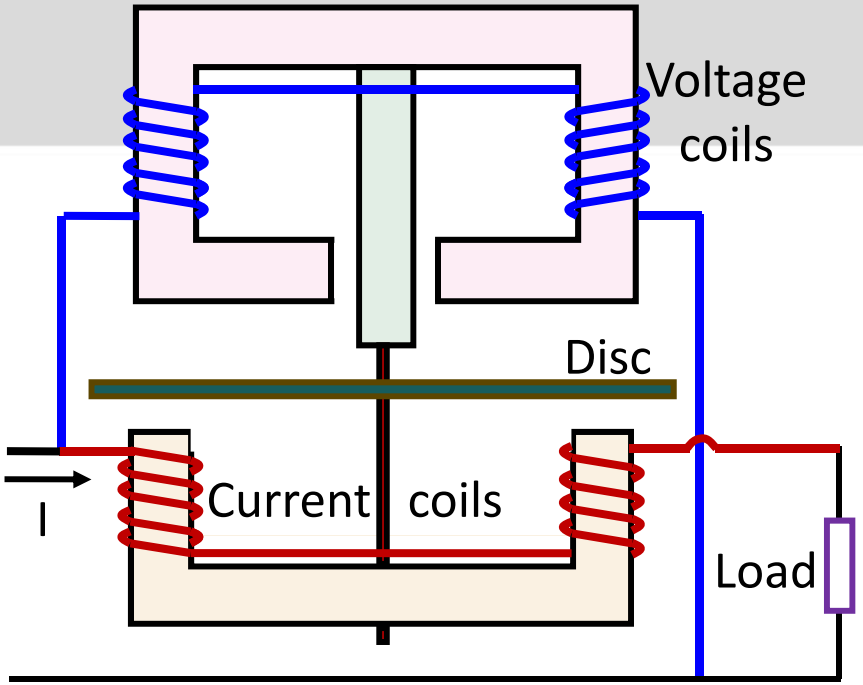
The torque is dependent on the measured power:

$$T_r = c \,.\, k \,.\, I\, V \cos \phi$$

The number of revolutions of the disc in a certain time is the measure of power:

$$\omega / t = c \,.\, k \,.\, I\, V \cos \phi$$

$$\omega \;\alpha\; t\; I\, V \cos \phi \quad \Longrightarrow \quad \omega \;\alpha\; \text{Energy}$$



The mechanical register counts the number of revolutions and hence indicates the load energy

Moving Iron instruments

Moving Iron instruments

Measuring instruments whose operation is based on the interaction between a magnetic field and a ferromagnetic-material core

The magnetic field is proportional to the quantity to be measured

Moving Iron instruments

The measured current is connected to the stationary coil producing a magnetic field that interacts with the moving iron element

The field pulls the core into the coil

A torque proportional to the square of the current is produced on the shaft

A spring is used to produce a counter torque proportional to the rotation angle

The shaft and pointer rotate with an angle proportional to the square of the quantity to be measured

The pointer comes to the steady-state when the torque and the counter torque are equal

Moving Iron instruments

Moving-iron voltmeter

the field coil is connected in parallel with the circuit

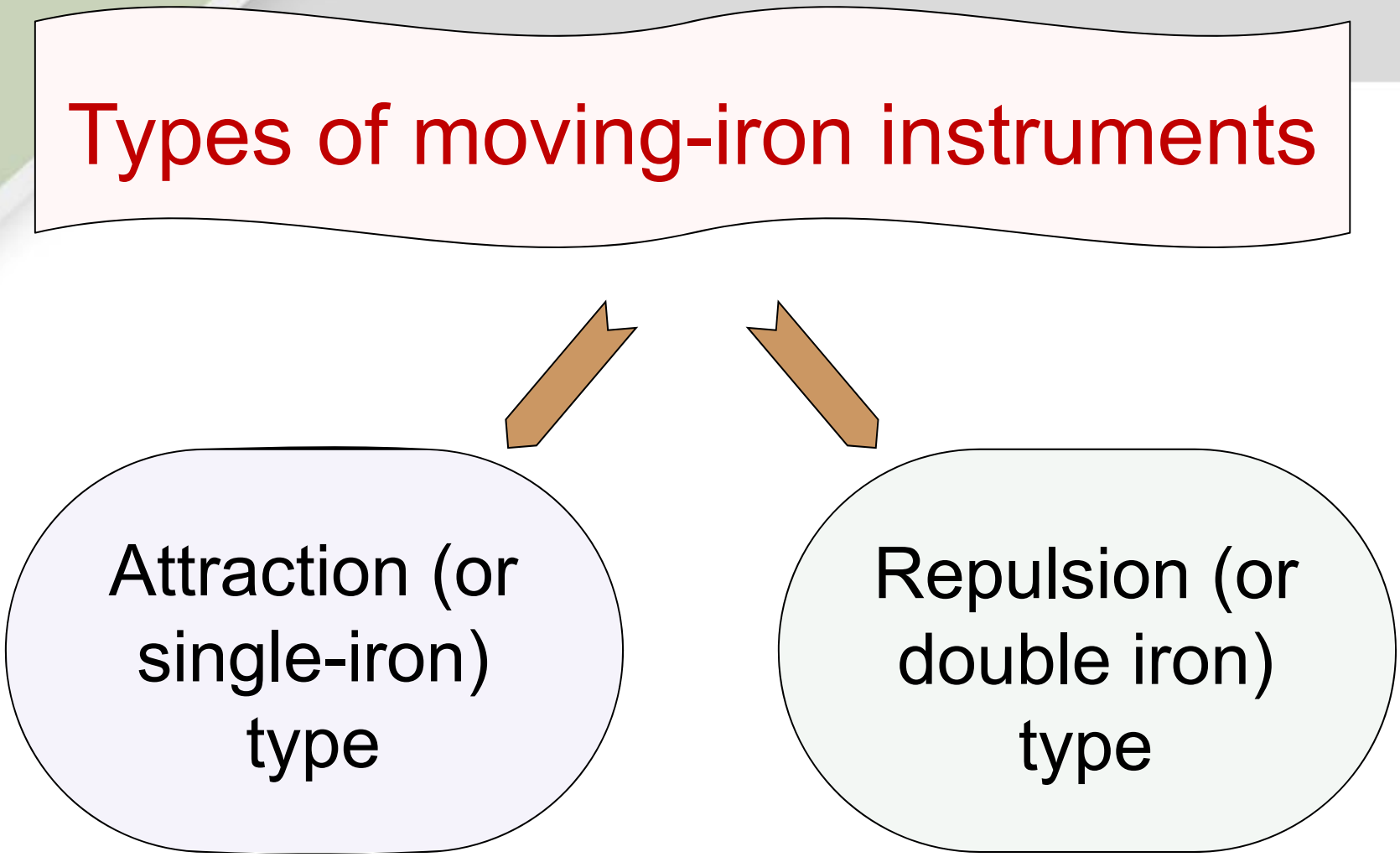
Moving-iron ammeter

The field coil is connected in series with the circuit

They are constructed mainly for measurements in

50 Hz circuits

Moving Iron instruments



Construction of moving iron instruments

Moving element (a piece of soft iron: a vane or rod)

Stationary coil: to produce the magnetic field

Fixed vane or rod magnetized with the same polarity (In repulsion type only)

Air chamber and a moving vane to produce damping torque

A spring or weight (gravity)